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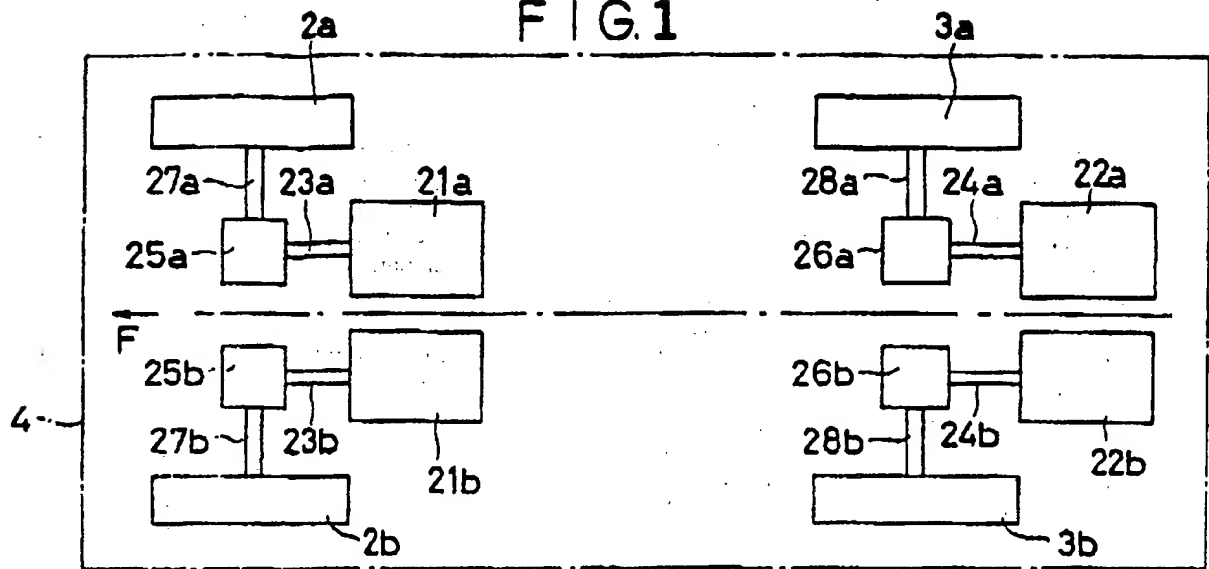
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EP 0 417 326 A1

(57) This invention relates to an improvement in driving performance of an electric car in which the driving wheels are driven by a motor. More specifically, the first feature of the present invention improves driving performance without making its mechanical construction complicated. The second feature of the present invention improves motion performance of the electric car by simplifying the structure of the steering wheels serving also as the driving

wheels and improving freedom of the turning operation of the steering wheels. To accomplish these objects, in an electric car equipped with the driving wheels (2a, 2b, 3a, 3b) on both sides of the car body, the present invention disposes independently the driving motors (21a, 21b, 22a, 22b) for them, controls independently these motors and applies further this structure to the steering wheels.

FIG. 1



## FIELD OF THE INVENTION

The present invention relates to an electric vehicle having wheels driven by electric motors, and particularly to improvements of the driving characteristics of the electric vehicle. PRIOR ARTS

With the advance of the recent automobile technology, there have been proposed several new technologies for improving the driving characteristics such as 4-wheel steering (4WS), 4-wheel driving (4WD), anti-skid brake system (ABS) and traction control.

However these new technologies are concerned with the handling of driving force of each of the front and rear wheels. And therefore, in order to carry out the above mentioned new technologies to the automobile, it is necessary to control each wheel properly, based upon the necessary conditions by adding new mechanical structures to the automobile structures of the prior art.

In general, the automobile is provided with steering wheels for changing the traveling direction of the vehicle and driving wheels for driving the vehicle. Recently, for improving the driving characteristics of vehicle and for securing a sufficient inside space of vehicle, there have been widely used a front-drive vehicle in which steering wheel also have a function of driving wheel and a 4WD vehicle.

## PROBLEMS TO BE SOLVED BY THE PRESENT INVENTION

In a conventional vehicle, it usually uses a driving system in which the power from a single power source (an engine) is divided into plural driving wheels. Accordingly, new mechanisms to be added for carrying out the above new technologies as well as the resulted mechanical structure into which the new mechanisms are incorporated, tend to complicate the mechanical structure of the vehicle, because of the driving system. This is quite same as in a case of an electric vehicle.

Especially in a case that the steering wheels have not only the steering function but also the driving function, it is necessary not only to swivel each of the steering wheels about its king pin shaft but also to impart the driving force to each of the steering wheels. Accordingly the mechanical structure becomes very complicated, for performing both the steering and driving functions.

It is therefore a main object to improve the driving characteristics of an electric vehicle and to provide an electric vehicle having a simple mechanical structure easily carrying out the new technologies mentioned above.

It is a second object to improve the driving characteristics of an electric vehicle by simplifying the structure of steering wheels having both the steering and driving functions and by increasing the degree of freedom of the swiveling motion of steering wheels.

## MEANS FOR SOLVING THE PROBLEMS AND EFFECTS

The first characteristic feature of the present invention for achieving the main object resides in an electric vehicle having driving wheels arranged at both sides of a body of vehicle wherein each of the driving wheels is respectively provided with an mutually independent driving motor and both the driving torque and the braking torque of each driving motor are adapted to be independently controlled based upon signals from the traveling conditions of the vehicle.

The second characteristic feature of the present invention for achieving the second object resides in an electric vehicle having steering wheels each mounted on its king pin shaft swivelably therearound and each being independently driven by each driving motor wherein each of the driving motors is formed by a stator arranged coaxially with an axle of each steering wheel and a rotor mounted on a wheel-rim of the steering wheel and adapted to be fitted around the stator.

According to the first feature of the present invention, it is possible to perfectly avoid all of the problems of the prior art concerning to the distribution of the driving force. And also it is easy to independently and freely varying the peripheral velocity, the driving force and the braking force of each of the driving wheels by independently controlling the driving torque and the braking torque of each of the driving motors.

It is therefore possible to easily carry out the new technologies mentioned above requiring careful control of the driving force of each wheel by a simple mechanical structure without a special mechanical structure and thus possible to improve the driving characteristics of an electric vehicle.

According to the second feature of the present invention, since each of the driving motors can be mounted on each steering wheel integrally therewith, it is possible to omit any mechanical structure for transmitting a power to each of the steering wheels requiring its swivel motion, and thus possible to simplify the mechanical structure of an electric vehicle.

Accordingly since the mechanical members disturbing the swivel motion of each steering wheel around its king pin shaft can be almost eliminated, it is possible to increase the swiveling angle of each steering wheel and thus possible to improve the driving characteristics of an electric vehicle.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 through 6 show a first embodiment of the present invention wherein Fig. 1 is a schematic plan view showing power transmitting apparatus of an electric vehicle of the present invention, Fig. 2 is a schematic side elevational view of an electric vehicle of Fig. 1, Fig. 3 is a block diagram showing a control apparatus of the power transmitting apparatus of Fig. 1, Fig. 4 is an explanatory drawing of 4WS function at a low-speed traveling mode, Fig. 5 is an explanatory drawing of 4WS function at a high-speed traveling mode and Fig. 6 is a flowchart showing the control an electric vehicle of Fig. 1; and

Figs. 7 through 13 show a second embodiment of the present invention wherein Fig. 7 is a sectional view taken along a line I-I in Fig. 12, Fig. 8 is an enlarged view of the upper portion of a king pin shaft, Fig. 9 is a sectional view of a driving motor, Fig. 10 is a perspective view of a rotor of a driving motor, Fig. 11 is a perspective view of a squirrel-cage rotor, Fig. 12 is a schematic plan view showing the arrangement of wheels of an electric vehicle of the present invention, Fig. 13 is an explanatory drawing showing the traveling condition of an electric vehicle of the present invention wherein Fig. 13 (a) is an explanatory drawing of an oblique traveling, Fig. 13 (b) is an explanatory drawing of a small-turn traveling, Fig. 13 (c) is an explanatory drawing of a spin-turn traveling, and Fig. 13 (d) is an explanatory drawing of a sidewise traveling.

#### EMBODIMENTS

In Figs. 1 through 6 there is shown an electric vehicle 1 of a first embodiment of the present invention. The electric vehicle shown is a 4-wheel drive type vehicle (hereinafter referred to "4WD" vehicle) having a function of 4-wheel steering (hereinafter referred to "4WS"), a function of anti-skid brake system (hereinafter referred to "ABS") and a function of traction control.

As shown in Figs. 1 and 2, the electric vehicle 1 of the present invention has two front wheels 2a and 2b arranged at both sides of the front direction (arrow F) of the vehicle, two rear wheels 3a and 3b and a body 4 supported on the front and rear wheels 2a and 2b; 3a and 3b. There are provided a

front seat 6 and a rear seat 7 within a cabin 5 formed by the body 4.

In front of the front seat 6, there is arranged a steering handle 8 to which the front wheels 2a and 2b are connected via a steering mechanism (not shown) including, for example, an Ackermann steering mechanism. Accordingly the front wheels 2a and 2b has a function of steering wheels.

An acceleration pedal 11 for controlling the rotational speed of the front and rear wheels 2a and 2b; 3a and 3b and a brake pedal 12 for operating a hydraulic braking system (not shown) are also arranged in front of the front seat 6.

Under the rear seat 7, there are arranged batteries 13 for supplying electric power to the driving motors each driving each of the front and rear wheels. A controller 14 for controlling each driving motor is also arranged behind the rear seat 7. Fig. 1 shows a power transmitting apparatus (i.e. a driving apparatus) of the electric vehicle 1 of the present invention.

Each of driving systems for right and left front wheels 2a and 2b and for right and left rear wheels 3a and 3b has a same mechanical structure. Front axles 27a and 27b respectively for the front wheels 2a and 2b and rear axles 28a and 28b respectively for the rear wheels 3a and 3b are drivingly rotated by driving motors 21a, 21b, 22a and 22b each forming a power source respectively for each of the front and rear wheels 2a, 2b, 3a and 3b via driving shafts 23a, 23b, 24a and 24b each extending respectively from the driving motors 21a, 21b, 22a and 22b and their gear boxes 25a, 25b, 26a and 26b.

Each of the driving motors 21a, 21b, 22a and 22b is driven by electric power from the batteries 13 and is independently controlled by signals from the controller 14.

The controller 14 for controlling the driving motors 21a, 21b, 22a and 22b of the electric vehicle 1 is constructed as shown in a block diagram of Fig. 3.

The controller 14 has a computer 31 and four motor-controllers 32a, 32b, 33a and 33b. The driving motors 21a, 21b, 22a and 22b are independently controlled by signals from the motor-controllers 32a, 32b, 33a and 33b.

Inputted into the computer 31 are following signals i.e. signals from wheel rotation detecting sensors 34 each mounted in conjunction with each of the driving motors 21a, 21b, 22a and 22b for detecting the rotational speed of each wheel (the signal(s) is (are) hereinafter referred to "wheel rotation signal(s)"), a steering angle signal from steering angle sensor 35 mounted on the column of the steering handle 8 (the signal is hereinafter referred to "steering signal"), an acceleration order signal detected by an acceleration sensor 36

mounted on the acceleration pedal 11 (the signal is hereinafter referred to "acceleration signal") and a brake order signal detected by a brake sensor 37 mounted on the brake pedal 12 (the signal is hereinafter referred to "brake signal").

If desiring to get a wheel rotation signal from a wheel which is not driven by any driving motor, the wheel rotation detecting sensor 34 can be mounted on the wheel itself or its axle.

The signals mentioned above are operated in accordance with a program stored in a memory means such as a ROM (Read Only Memory) in the computer 31 and are compared with traveling data of the electric vehicle 1 stored in the memory means. The outputs from the computer 31 are inputted into the motor-controllers 32a, 32b, 33a and 33b of the driving motors 21a, 21b, 22a and 22b to properly control the rotational condition thereof to obtain the optimum driving force and braking force of each wheel.

The functions of 4WS, 4WD, ABS and traction control of this embodiment will be hereinafter described in more detail.

Firstly the 4WS function at a low-speed traveling mode will be described with reference to Fig. 4.

A point MO is a turning center of the vehicle 1 when the vehicle 1 is steered by the steering handle 8 in a conventional manner. Whereas when the vehicle 1 is controlled by driving the radially outward front wheel 2a and rear wheel 3b at driving forces  $\Delta F1$  and  $\Delta F3$ , respectively and by driving the radially inward front and rear wheels 2a and 3a at a driving force  $\Delta F2$  smaller than the driving forces  $\Delta F1$  and  $\Delta F3$  or by braking the radially inward front and rear wheels 2a and 3a at braking forces  $\Delta R2$  and  $\Delta R4$ , a steering effect similar to a caterpillar type vehicle is arisen between the right and left rear wheels 3a and 3b. Accordingly the turning center of the vehicle 1 occupies a position M which is nearer to the body of vehicle 1 than the position MO and the turning radius of the vehicle is reduced. That is, the 4WS effect is thus easily achieved according to the present invention.

It is preferable to carry out the control of the 4WS drive mentioned above under a condition that all of the resultant force of the driving forces arisen in each wheel in forward and rearward directions become equal, so that no acceleration toward the traveling direction of the vehicle 1 is generated and thus the stability in travel of vehicle is improved.

Then the 4WS function at a high-speed traveling mode will be described with reference to Fig. 5.

In general, when a vehicle turns at a high speed, the vehicle tends to travel more inward direction relative to the instantaneous traveling direction of the vehicle due to an excessive yawing moment of vehicle.

This embodiment of the present invention in-

tends to improve the stability of vehicle at high speed traveling, by controlling the driving force and the braking force of each wheel, and by generating a moderate yawing moment canceling the excessive yawing moment, to make the instantaneous traveling direction of vehicle coincident with the direction of the body of vehicle.

When the vehicle 1 is given a right hand turn, an excessive yawing moment in right hand direction around the center of gravity of the vehicle 1 is generated. By providing variations in driving force  $\Delta F2$  and  $\Delta F4$  and variations in braking force  $\Delta R1$  and  $\Delta R3$  in each wheel and thus by generating a yawing moment of left hand direction in the body of vehicle 1 with the control of each driving motor, said yawing moment of right hand direction will be cancelled out and the attitude of vehicle is thus stabilizingly controlled.

It is preferable, in this case, to use a regenerative braking force of each driving motor as a braking force to be applied to each wheel.

Similarly to the case of the 4WS drive at a low-speed mode, it is also preferable to carry out the control of the 4WS drive at a high-speed mode under a condition that all of the resultant force of the driving forces arisen in each wheel in forward and rearward directions become equal so that no acceleration toward the traveling direction of the vehicle 1 is generated.

According to the present invention it is possible to carry out 4WS function only by properly control the driving motor of each wheel without any other special mechanism and also possible to improve the stability in travel of vehicle.

Then the function of 4WD will be described. Since in the electric vehicle 1 of the present invention each of the wheels 2a, 2b, 3a and 3b is provided with individual driving motors 21a, 21b, 22a and 22b respectively, the function of full-time 4WD can be easily achieved by so controlling each driving motor that the rotational speed of the wheels on traveling in a straight direction becomes identical each other.

In general, when a vehicle having a selective type 4WD function turns under a 4WD mode, a braking phenomenon is sometimes caused because of the difference in traveling distance between the radially outward wheels and radially inward wheels and because of absence of any differential motion means between the front wheels and rear wheels.

In the electric vehicle 1 of the present invention, since each wheel 2a, 2b, 3a and 3b is provided with the driving motor for individually driving its related wheel, it is possible to improve the braking phenomenon by properly controlling the driving motors so that the rotational speed of the driving motors (e.g. the driving motor 22a) for the

radially inward wheels (e.g. the rear wheel 3a having a smallest turning radius) becomes lower than the rotational speed of the driving motors (e.g. the driving motor 21b) for the radially outward wheels (e.g. the front wheel 2b having a largest turning radius).

Then the function of ABS of the electric vehicle 1 of the present invention will be described. According to the present invention, the braking force and the driving force of each driving motor are adapted to be determined or corrected by determining the angular acceleration of each wheel based upon the wheel rotation signals from the wheel rotation sensors 34 each mounted on each of the wheels 2a, 2b, 3a and 3b, by determining the required braking force and the required angular acceleration of each wheel from braking signals, steering signals, speed of vehicles and e.g. previously stored limit braking force, and by considering the road surface conditions.

The limit braking force can be determined by operating signals from each of the sensors and the adjustment of the braking force can be achieved by adjusting the regenerating braking force and the driving force of each of the driving motors.

According to the present invention, since the driving force and the braking force of each of the driving motors are corrected, the driving force and the braking force of each of the driving motors do never exceed the limit braking force, prevent the skid of the vehicle 1 during its being braked and thus the function of ABS can be obtained. Then the function of the traction control of the present invention will be described. Previously stored in the memory means of the computer 31 is a limit value of the rotational angular acceleration of each wheel of the vehicle 1 of this embodiment which can be adapted to a road surface condition having a small coefficient of friction such as a snow-covered road. The driving force of each driving motor can be determined by the rotational angular acceleration of each wheel from the wheel rotation signal and the required angular acceleration of each wheel which can be obtained by operating the required driving force and the required angular acceleration of each wheel, and by considering the road surface condition.

The limit driving force may be determined by an operated value of a signal from each sensor.

According to the present invention, the result of operation do never exceed said limit value although the acceleration order exceeds the limit driving force. Accordingly, the rotation of the wheel under the driving force exceeding the limited value is thus prevented and therefore the function of traction control can be obtained by limiting the transmission of the acceleration order to each driving motor.

In this case, if simultaneously detecting the braking force, it will be able to surely prevent the slippage of the vehicle on the road having a small coefficient of friction due to the contribution of said ABS function.

The signals from the sensors are processed by the computer 31 along a program shown in Fig. 6 in order to effectively exhibiting all of the functions mentioned above.

First of all, the wheel rotation signals from the wheel rotation sensors 34 each mounted on the driving motors 21a, 21b, 22a and 22b of the wheels 2a, 2b, 3a and 3b are inputted into the computer 31 and the speed of the vehicle 1 is operated therefrom (STEP "A").

Then the acceleration signal from the acceleration sensor 36 arranged at the acceleration pedal 11 and the braking signal from the brake sensor 37 arranged at the brake pedal 12 are inputted into the computer 31, and the computer 31 determines from these acceleration signal and the braking signal whether the vehicle 1 is decelerated or not (STEP "B"). It goes to a STEP "C" when on deceleration and to a STEP "G" when on acceleration or constant speed.

The required braking force and the required angular acceleration are operated from the braking signal, the vehicle speed and the limit braking force at the STEP "C" and then it goes to a STEP "D".

The braking force (torque) and the driving force (torque) of each driving motor are operated in consideration of the road surface condition from the angular acceleration of each wheel obtained from each wheel rotation signal and the required angular acceleration of wheel at the STEP "D" and then it goes to a STEP "E".

It is determined at the STEP "E" by the steering signal from the steering angle sensor 35 whether the vehicle 1 is now on turn or not and it goes to a STEP "F" in case of "yes" and it is outputted to the motor controller in case of "no".

The required angular acceleration of wheel is corrected at the STEP "F" comparing with the limit braking force in consideration of the cornering force due to the turn of the vehicle 1 and then the operated results of the amount of control of each driving motor are outputted to each motor controller.

The STEPS "D" through "F" correspond to the ABS function.

When determined as "not on deceleration" at the STEP "B" above, it goes to a STEP "G" and the required driving force and the required angular acceleration of wheel are operated from the acceleration signal, the vehicle speed and the limit driving force at this STEP "G" and then it goes to a STEP "H".

The braking force and the driving force of each

driving motor are operated at the STEP "H" in consideration of the road surface condition from the angular acceleration of each wheel obtained from each wheel rotation signal and the required angular acceleration of wheel and it goes to a STEP "J".

These STEPS "G" and "H" correspond to the function of traction control.

It is determined at a STEP "J" by the steering signal from the steering angle sensor 35 whether the vehicle is now on turn or not. It goes to a STEP "K" in case of "yes" and the operated result of the amount of control of each driving motor is outputted to each motor controller.

The driving force and the braking force are operated at the STEP "K" to obtain the corrected value (the braking phenomenon preventing function on traveling at 4WD mode) from the steering signal and each wheel rotation signal in consideration of the difference in the traveling distance between the radially inward wheels and the radially outward wheels and then it goes to a STEP "L".

It is determined at the STEP "L" from said vehicle speed whether the vehicle is traveling at a high speed or not and it goes to a STEP "P" in case of "yes" and to a STEP "Q" in case of "no".

When determined at the STEP "L" that the vehicle is traveling at a high speed, the yawing moment of the vehicle 1 is operated at the STEP "P" from the steering signal, each wheel rotation signal and the vehicle speed to obtain the corrected value of each driving force for cancelling the yawing moment (the 4WS function on traveling at a high speed).

When determined at the STEP "L" that the vehicle is not at a high speed travel, the difference in the driving force between the driving wheels to minimize the turning radius of the vehicle is operated from the steering signal, each wheel rotation signal and the vehicle speed to obtain a corrected value of the driving force of each driving wheel (the 4WS function on travelling at a low speed).

The corrected value of each driving force thus obtained is then inputted to the motor controller of each driving motor and is used to properly adjust the driving force and the braking force of each wheel.

As described above, according to the embodiment of the present invention, since the control system is constructed as a single computer system and is adapted to achieve the travel control and the attitude control of the vehicle by effectively utilizing the signals obtained during the travel of the vehicle and by controlling the driving force and the braking force of each wheel, it is possible to improve the stability in travel of the vehicle and thus the driving characteristics of the electric vehicle.

Although shown above is the embodiment provided with four functions of 4WS, 4WD, ABS and

traction control, it is not necessarily provide the vehicle with all of these functions.

According to the first embodiment of the present invention, it is possible to solve all of the problems relating to the distribution of the driving force in the prior art and is also easy to freely and independently varying the peripheral velocities and the driving forces of the wheels of both sides of the vehicle.

Accordingly it is easy to carry out the new technologies such as 4WS, 4WD, ABS and traction control which require the adjustments of driving force etc. of each wheel and also can carry out the new technologies with the use of a relatively simple mechanical structure and thus can improve the driving characteristics of the electric vehicle.

The second embodiment of the present invention will be described with reference to Figs. 7 through 13.

An electric vehicle 51 (Fig. 12) of the second embodiment is a 4-wheeled automobile having a 4WS function wherein each wheel of the vehicle is mounted on a king pin shaft, swivelably therearound. The construction of a steering mechanism, a driving mechanism and a suspension mechanism (Fig. 12) are clearly shown in Fig. 7.

In Fig. 7, a numeral 52 denotes a wheel and a numeral 53 denotes a frame.

A supporting means 54 is secured on one side of the frame 53 and has a through bore 54a. Bearings 54b are arranged at top and bottom ends of the bore 54a.

The wheel 52 is mounted on the bottom end of king pin shaft 55 which is passed through the bore 54a of the supporting means 54.

The upper portion of the king pin shaft 55 is integrally formed with a flange portion 55a and the lower end portion of the king pin shaft 55 is integrally secured a base plate 57 by welding and other suitable ways. The base plate 57 forms a frame for a driving motor hereinafter mentioned and is adapted to horizontally support an axle 65.

A coil spring 54d is interposed between a washer 54c mounted on the upper surface of the flange portion 55a and the lower surface of the upper bearing 54b secured on the supporting means 54. The king pin shaft 55 is vertically movable relative to the supporting means 54 and also is movable around its own axis.

A boss 71 and a boss aperture 74 is formed at the center of the base plate 57. A stator coil 73 is secured around the outer circumferential surface of the boss 71 and an axle 65 of the wheel 52 is rotatably mounted in the boss aperture 74 (see Fig. 9).

The axle 65 is rigidly fixed to a rotor frame 76 to which is secured to a wheel rim 61 of the wheel 52. The axle 65 is projected inside the base plate

57 and a brake disc 66 is secured on the inner end of the axle 65.

A brake caliper 67 supported on the base plate 57 is so arranged that it faces the peripheral surfaces of the brake disc 66 to provide the braking action thereto. In Fig. 7, a numeral 68 denotes a tire of the wheel 52.

A worm wheel 64 is secured on the end of the king pin shaft 55 above the supporting means 54 and a worm 63 driven by a geared motor 62 is arranged near the worm wheel 64 to mesh therewith.

When driving the geared motor 62, the wheel 52 is steered via the king pin shaft 55, base plate 57 and the axle 65.

The worm wheel 64 is fitted on a splined portion 55g of the king pin shaft 55 and therefore it is always kept in a matching position with the worm 63 and enables the power transmission therebetween despite of the vertical movement of the king pin shaft 55.

As shown in Figs. 9 through 11, an outer-rotor type induction motor 56 is constructed as a wheel driving motor between the base plate 57 and the rim 61 of the wheel 52.

That is, the driving motor 56 comprises a stator 58 and a rotor 59. A yoke 72 formed by a plurality of laminated steel plates is mounted on the boss portion 71 therearound and a stator coil 73 is wound in the yoke 72.

The axle 65 forming a shaft of the rotor 59 is rotatably supported by bearings 75 arranged within the aperture 74 of the boss portion 71.

As shown in Fig. 10, the rotor 59 is formed by the rotor frame 76 and the axle 65 arranged at the center of the rotor frame 76.

The squirrel-cage rotor 77 shown in Fig. 11 is fitted within the rotor frame 76 along the inner peripheral surface thereof.

The squirrel-cage rotor 77 is formed by two end rings 78 and a plurality of conductors 79 and acts as a rotor coil generating a rotational force relative to the stator coil 73.

The driving motor 56 is thus formed by inserting the shaft of the rotor 59 i.e. the axle 65 into the bearings 75 mounted in the aperture 74 of the boss 71 of the stator 58.

That is, when the axle 65 is properly mounted into the bearings 75, the squirrel-cage rotor 77 forming the rotor coil is so arranged that it covers the periphery of the stator coil 73 mounted around the boss 71. Accordingly the rotor 59 is rotated around the boss aperture 74 of the stator 58 when the power for the driving motor is switched on.

According to the driving motor 56 of the second embodiment of the present invention, since the rotor 59 is rotatably positioned around the stator 58, it is easy to form the driving motor 56 by

merely connecting the rotor frame 76 of the rotor 59 to the rim 61 of the wheel 52 by using fastening means such as bolts.

In this embodiment the electric power is supplied to the driving motor 56 via a joint portion 69 arranged above the king pin shaft 55.

As shown in Fig. 8, the joint portion 69 comprises slip rings 55c which are electrically isolated each other by isolating rings 55b and carbon brushes 55d each contacting with the peripheral surface of each slip ring 55c. Electric cables connected to the slip rings 55c are passed through an aperture 55e formed in the king pin shaft 55 and are led to the driving motor 56.

In this embodiment, the aperture 55e formed in the king pin shaft 55 also has a function of a passage of the pressurized liquid supplied via a swivel joint 55 for operating the brake caliper 67.

As described above, according to the structure of the present invention, since the driving means for each wheel 52 i.e. the driving motor 56 comprises the stator 58 arranged coaxially with the axle 65 and the rotor 59 formed in the rim 61 of each wheel 52 and fitted around the stator 58, it is possible to eliminate any mechanical power transmission structure to impart the driving force to each wheel 52.

Accordingly it is possible to effectively utilize the large space left at the side of each wheel 52 and therefore to much more increase the steering angle (i.e. the swiveling angle of the wheel 52) than that of the prior art and thus to drive the vehicle in various manners which are difficult in a vehicle of the prior art.

For example, a vehicle 51 having such four wheels 52 will be driven same as the vehicle 1 of the first embodiment by controlling each driving motor 62 of each wheel 52. Further by properly controlling each geared motor 62 of each wheel 52, it is possible to drive the vehicle 51 in various manners as shown in Fig. 13. An arrow "F" in Fig. 13 shows a front direction of the vehicle 51.

When all of the wheels 52 are directed in an oblique direction as shown in Fig. 13(a), the vehicle 51 can continue an oblique travel keeping the attitude of the vehicle 51 in the constant oblique direction.

This means that the vehicle 51 can change the traffic lane keeping its stable attitude although during a high speed travel.

When the direction of the front wheels 52a and 52b is directed opposite to that of the rear wheels 52c and 52d as shown in Fig. 13(b), it enables the vehicle 51 turn at a smaller turning radius.

Further when the direction of each of the front wheels 52a and 52b and the direction of each of the rear wheels 52c and 52d are directed opposite each other as shown in Fig. 13(c), it enables the



vehicle 51 turn around the turning center positioned within the vehicle body (the so-called as "spin turn") and further improve the motion characteristics of the electric vehicle 51.

When all of the wheels 52 are directed transversely to the front direction "F" of the vehicle 51 as shown in Fig. 13(d), it enables the vehicle 51 move in a sidewise direction and thus makes the column parking of the vehicle 51 very easy.

According to the present invention, since the driving motor 56 of each wheel 52 is adapted to be positioned within the rim 61 of each wheel 52, a large projection required in the prior art for the installation of the driving motor is eliminated and therefore a large space can be maintained between the wheels 52.

Although the present invention has been described with respect to a four-wheeled 4WS vehicle, it can be easily understood that the present invention can be applied similarly to a front wheel driving vehicle or a rear wheel driving vehicle having a rear wheel steering mechanism.

According to the second embodiment of the present invention, since the driving motors of wheels can be installed integrally with the steering wheel, it is possible to eliminate the power transmitting mechanisms to the steering wheels and thus simplify the mechanism of the vehicle.

This can reduce the structural members which would disturb the turning action of the steering wheels around their king pin shafts and thus can increase the angular range of turning action of the steering wheels and therefore can improve the motion characteristics of the vehicle.

#### Claims

1. An electric vehicle provided with driving wheels at both sides of the body of the vehicle characterized in that:  
said vehicle comprising driving motors each independently driving each driving wheel, the driving torque and the braking torque of each driving motor are independently controlled by signals based upon the travel of the vehicle.
2. An electric vehicle according to claim 1 wherein further comprising wheel rotation sensors each detecting a wheel rotation signal of each wheel, a steering angle sensor detecting a steering angle, an acceleration sensor detecting the acceleration condition of the vehicle and a brake sensor detecting the braking condition of the vehicle, and wherein each of the driving motors is independently controlled by operating the signals from said sensors.

3. An electric vehicle having steering wheels each being able to swivel around its king pin shaft and also being rotated by its driving motor characterized in that:

said driving motor comprising a stator arranged coaxially with an axle of the steering wheel and a rotor mounted on a rim of the steering wheel and adapted to be fitted around the stator.

4. An electric vehicle according to claim 3 wherein further comprising a base plate supported by the king pin shaft at the bottom and thereof, a boss portion projected from the base plate and formed therein a horizontally extending boss aperture, the stator of the driving motor being formed around the boss portion, and the axle of the steering wheel also having a function of a shaft of the rotor being inserted into the boss aperture.

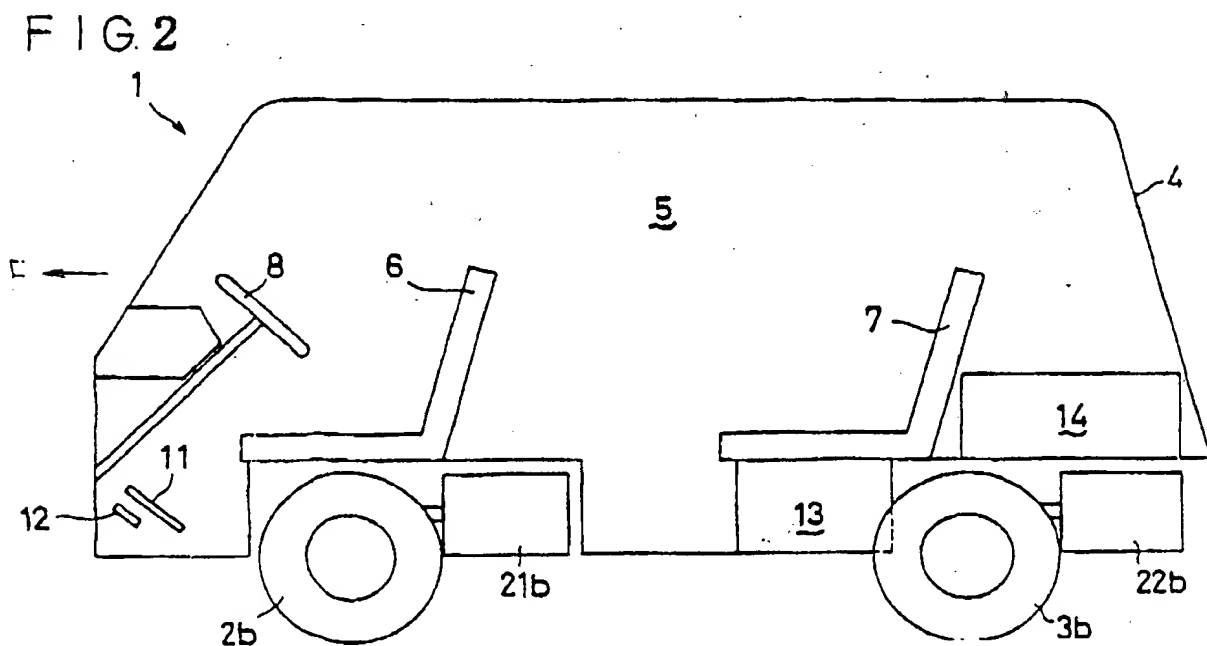
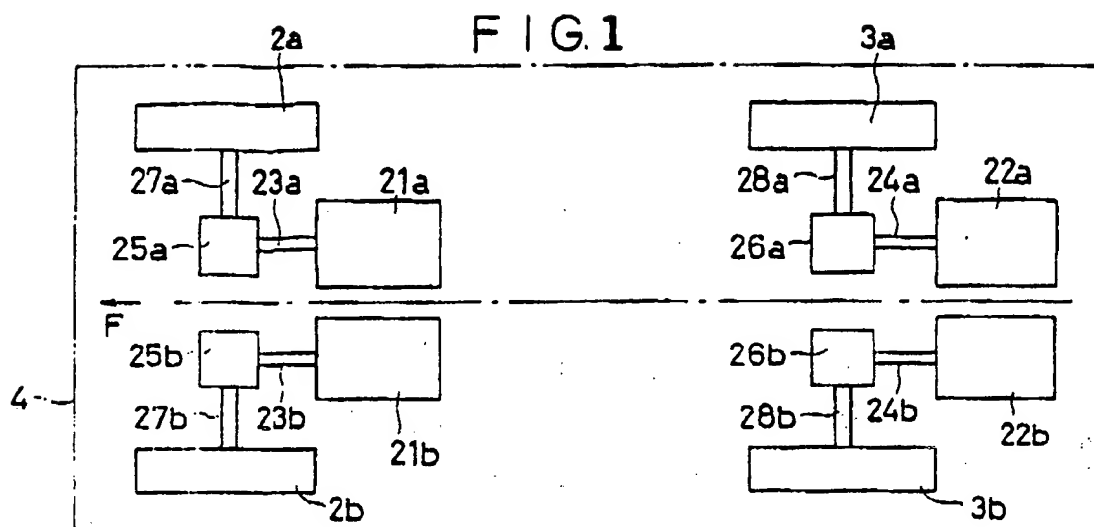


FIG. 3

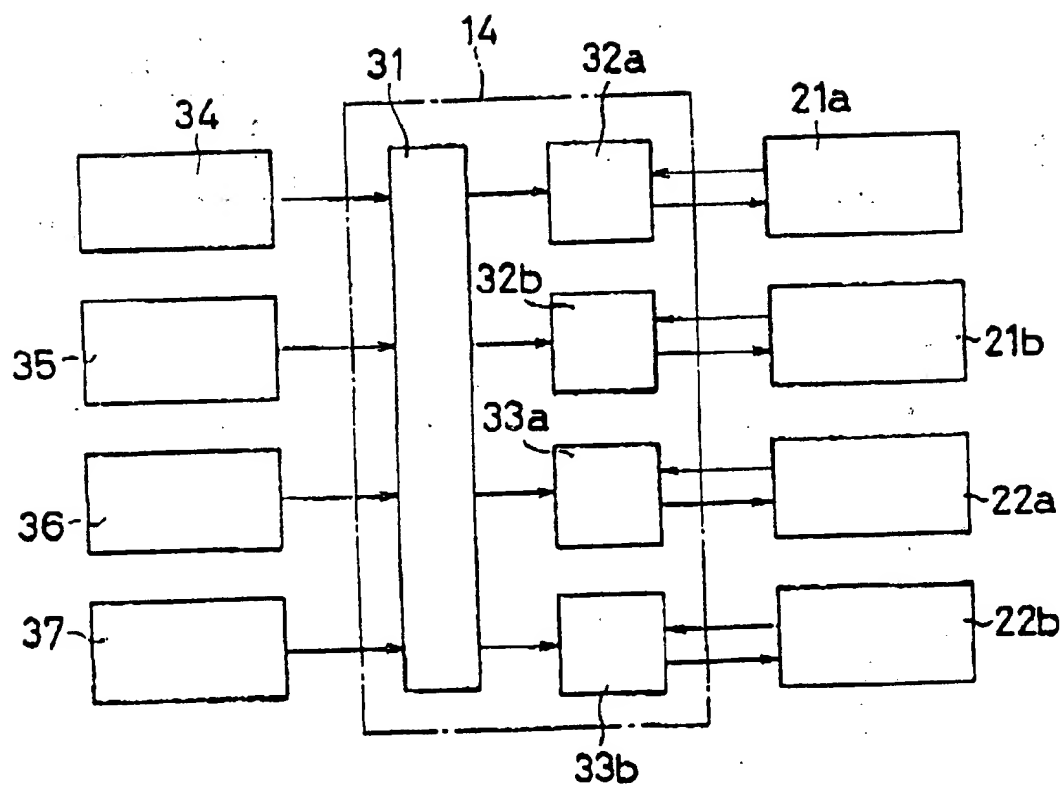


FIG 4

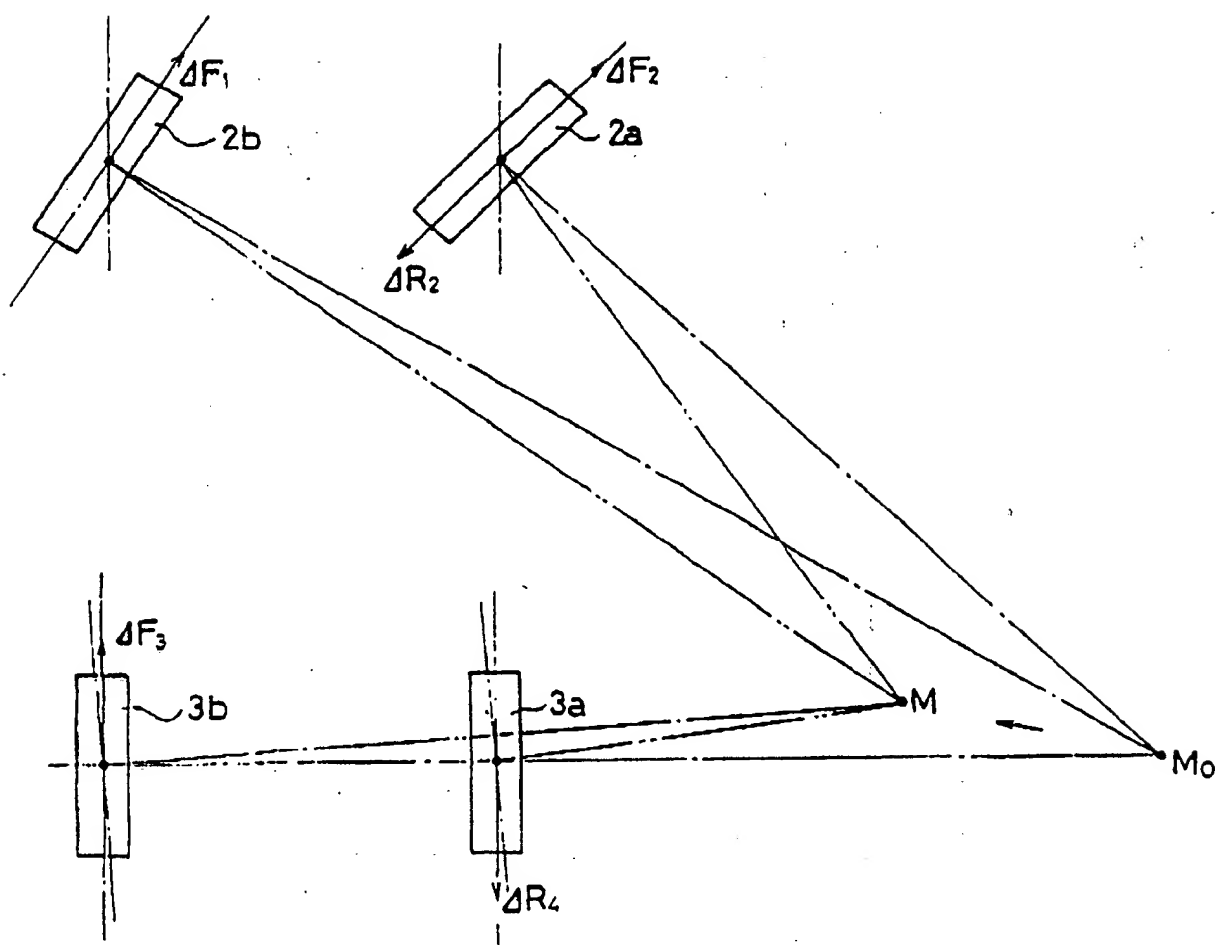
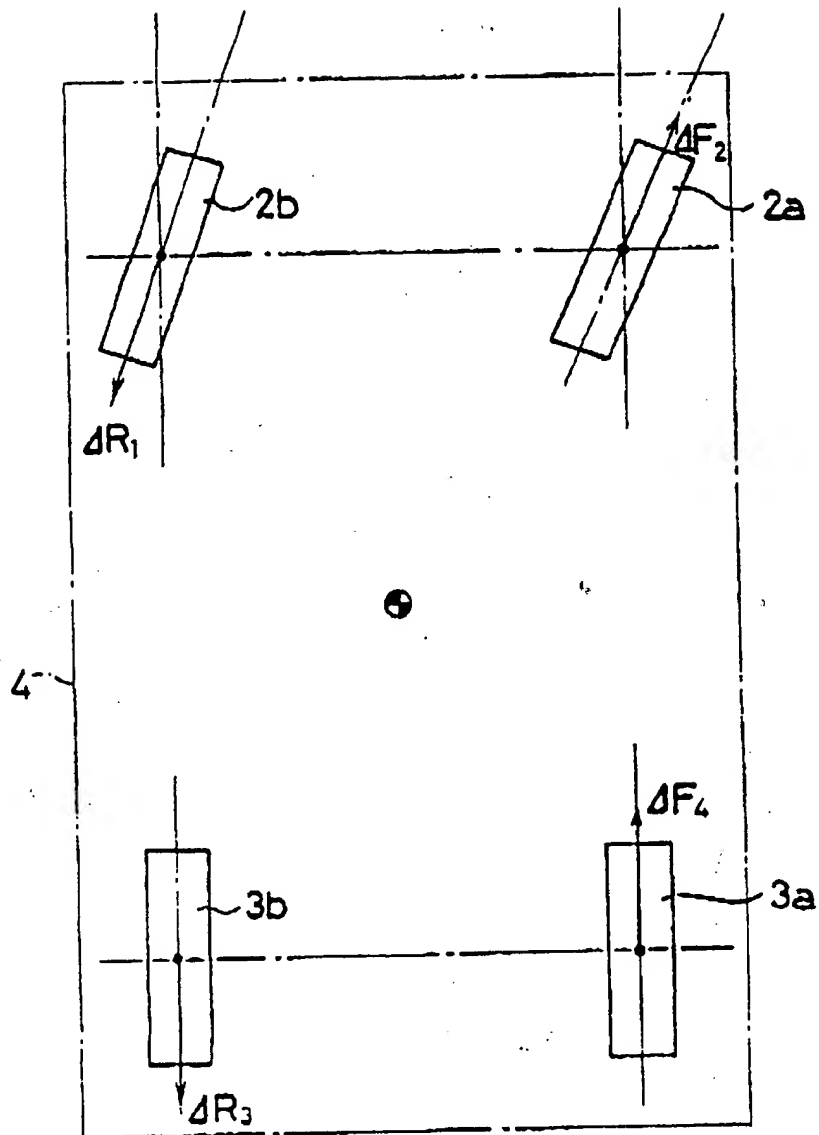


FIG. 5



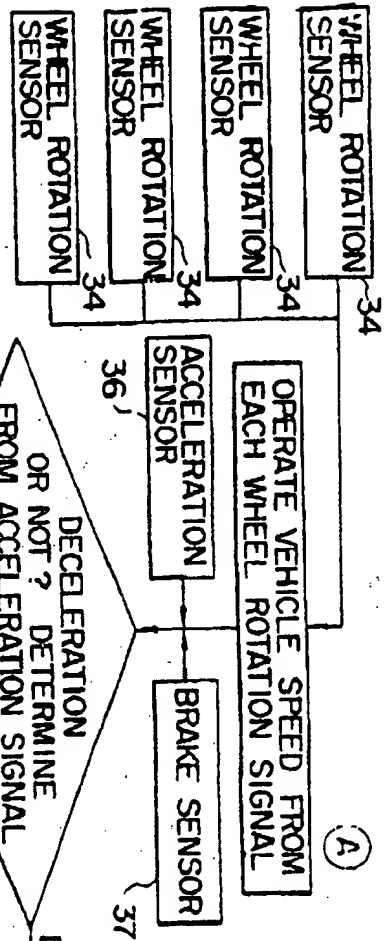


FIG. 6A

FIG. 6

FIG. 6A

FIG. 6B

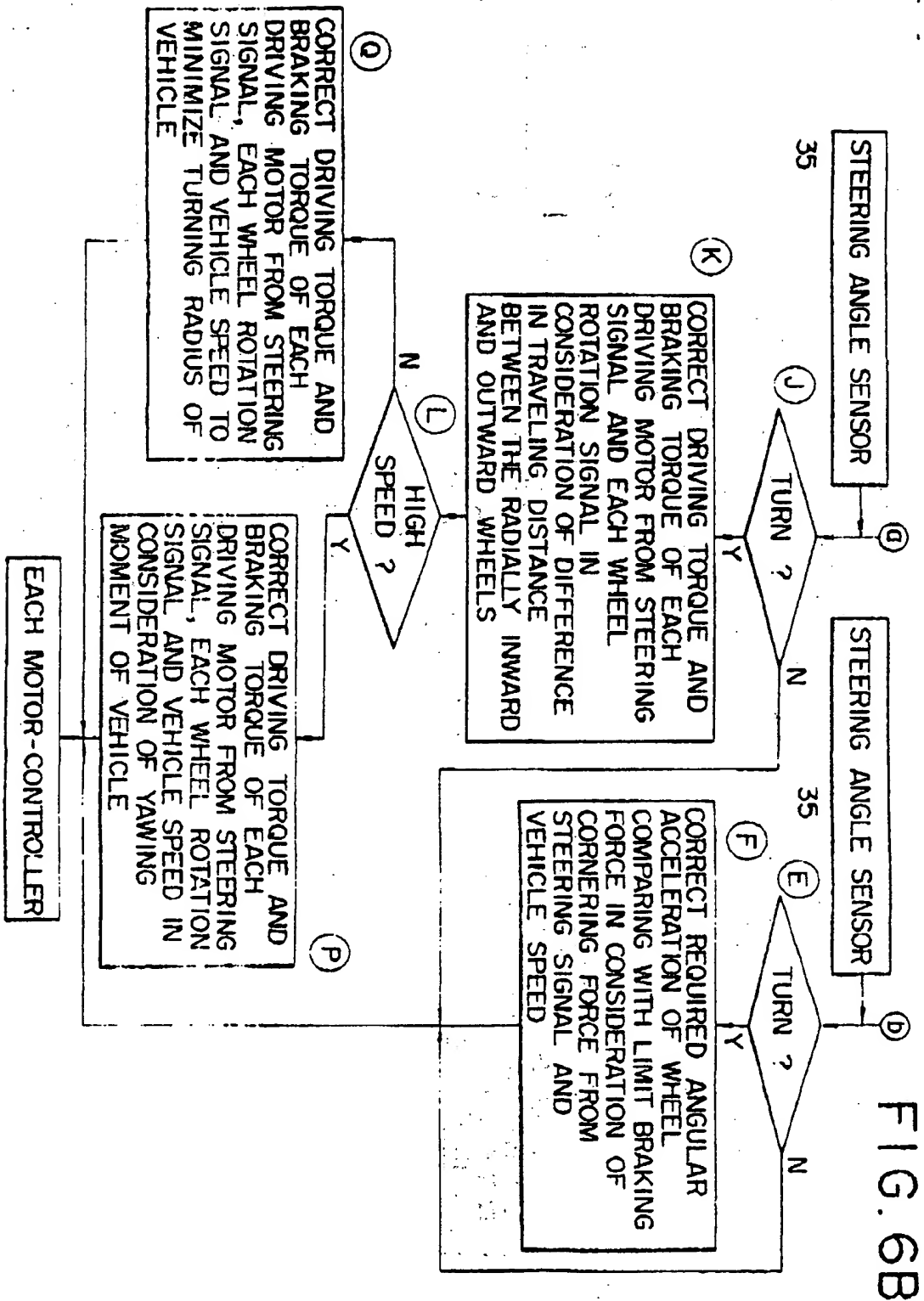


FIG. 7

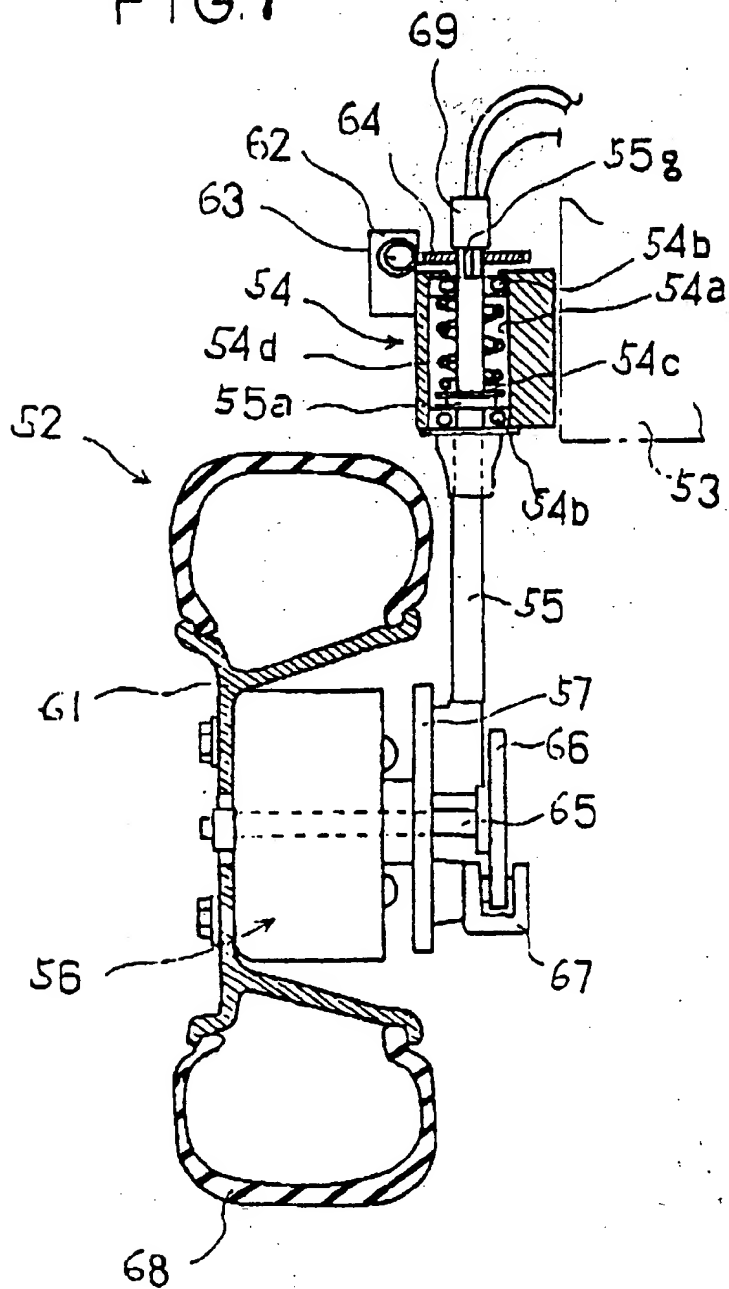


FIG. 8

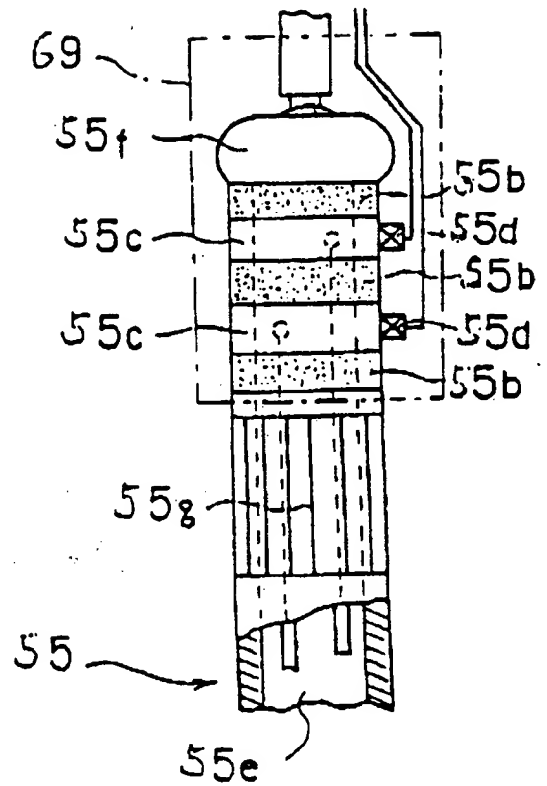




FIG. 9

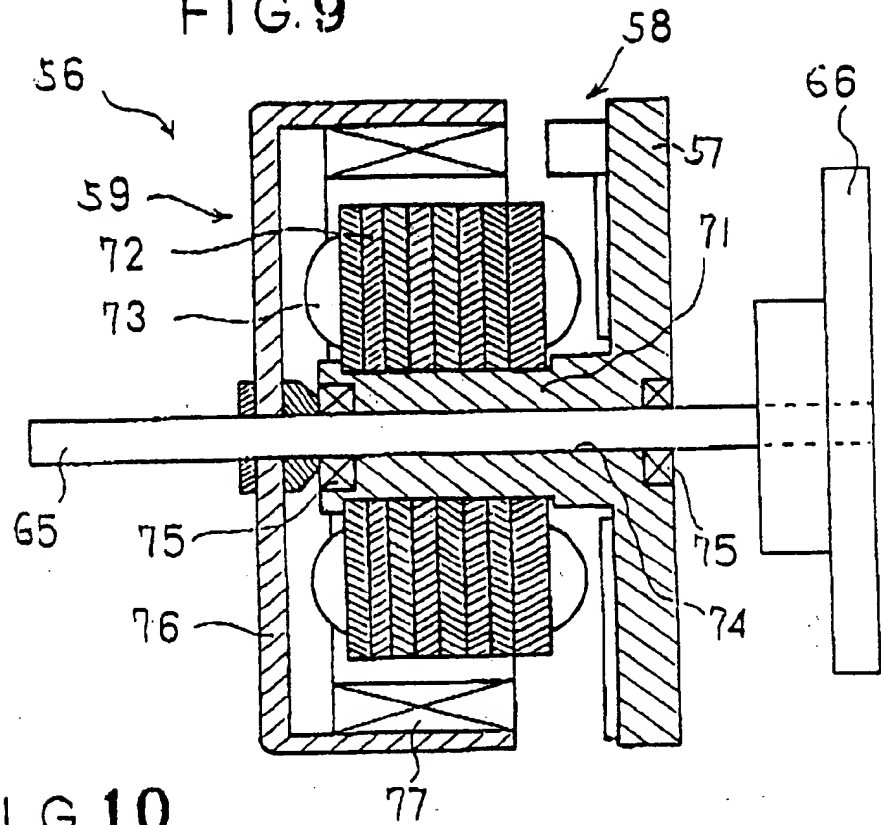


FIG. 10

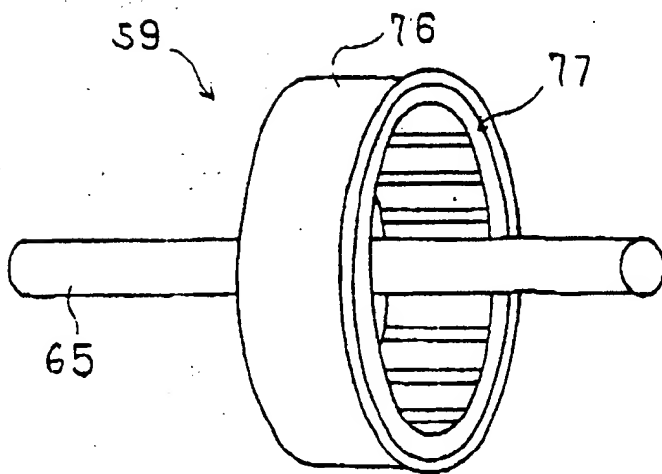


FIG. 11

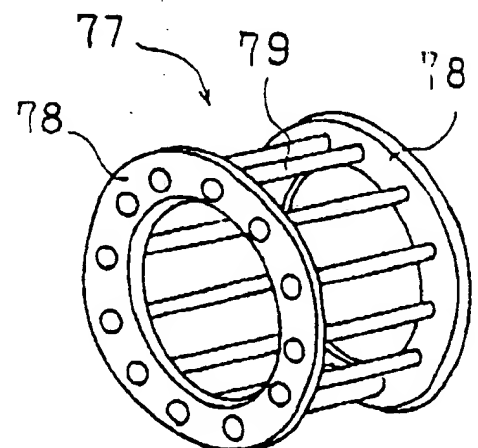


FIG. 12

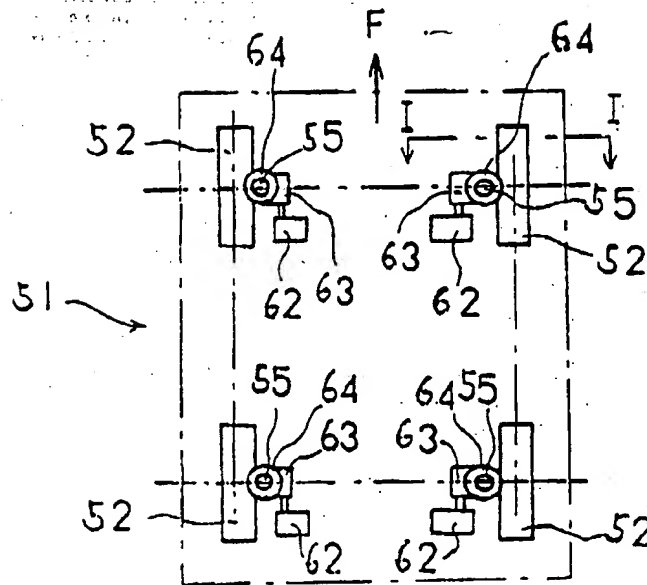
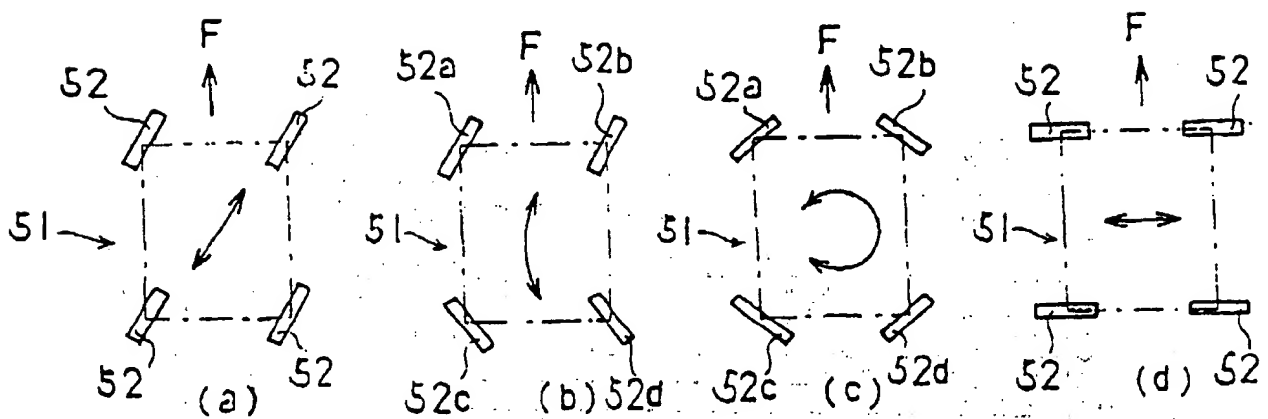


FIG. 13



# INTERNATIONAL SEARCH REPORT

International Application No PCT/JP90/00436

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) *		
According to International Patent Classification (IPC) or to both National Classification and IPC		
Int. Cl <sup>5</sup> B60K7/00, B60K1/00		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched *		
Classification System	Classification Symbols	
IPC	B60K1/00, 7/00	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched *		
Jitsuyo Shinan Koho 1933 - 1988 Kokai Jitsuyo Shinan Koho 1933 - 1988		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT *</b>		
Category *	Citation of Document, <sup>11</sup> with indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	JP, A, 49-49324 (Takashi Kondo), 13 May 1974 (13. 05. 74), (Family: none)	1
X	JP, A, 59-190056 (Yoichi Saito), 27 October 1984 (27. 10. 84), (Family: none)	1, 2
Y	JP, Y1, 50-13631 (Toyota Motor Corp.), 25 April 1975 (25. 04. 75), (Family: none)	3
Y	JP, U, 62-139814 (Tokyo R & D K.K.), 3 September 1987 (03. 09. 87), Fig. 3 (Family: none)	4
<p>* Special categories of cited documents: <sup>10</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"S" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search		Date of Mailing of this International Search Report
June 13, 1990 (13. 06. 90)		July 2, 1990 (02. 07. 90)
International Searching Authority		Signature of Authorized Officer
Japanese Patent Office		

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